

The Q Wave in L III and aVF of the Electrocardiogram

A Vectorcardiographic Analysis with the Use of the Frank System

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A COMMON PROBLEM in electrocardiography is presented by the presence of a Q wave in Lead III and/or aVF: Does it or does it not indicate an inferior myocardial infarction? Frequently, in inferior myocardial infarction, the Q wave decreases in amplitude and duration after the acute phase, to the point that it no longer satisfies the criteria for this diagnosis.¹⁵ Several rules have been established to interpret the significance of the Q wave in these leads. All of them are based on configuration, magnitude and duration of the Q wave.* With vectorcardiography, it was hoped that this problem might be solved, especially with the corrected orthogonal lead systems.

The present study was undertaken in order to test the value of vectorcardiography in the study of the Q wave in L III and aVF of the electrocardiogram with the use of a Frank lead system.

MATERIAL AND METHODS

Seventy-three consecutive patients were studied. The criteria for selection were based entirely on the presence of a Q wave in Lead III and/or aVF and the absence of abnormalities characteristic of myocardial infarction in other leads. The presence of a Q wave in Lead II was not a requirement for inclusion of a patient in this study. All patients had a 12 lead electrocardiogram (ECG) recorded with a direct-writer Sanborn electrocardiographic machine. All patients had sinus rhythm; those with bundle-branch block were excluded.

The vectorcardiograms (VCG) were recorded by use of a Hart Electronics Model PV3 vectorcardiographic machine.[†] The loops were photographed from the oscilloscope with a Polaroid® camera, using a 3,000 speed polaroid land film.

*See References Nos. 1, 3, 4, 7, 9, 10, 13, 14, 16, 19, 20, 22.
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• Seventy-three consecutive patients with a Q wave in Lead III and aVF in the electrocardiogram were studied. Vectorcardiograms were recorded with the use of the Frank system.

In 32 cases the ECG's were compatible with the diagnosis of an inferior myocardial infarction based on a Q wave in Lead III and/or aVF greater than 0.04 second duration and greater than 25 per cent of the amplitude of the R wave. In this group, there were 16 patients with coronary disease and the VCG confirmed the electrocardiographic diagnosis of an infarction in 14 cases. In 13 of the other 16 cases without history of coronary disease the VCG did not suggest the presence of an infarction.

In all 17 cases with questionable electrocardiographic diagnosis of an inferior infarction, and without history of coronary disease, the VCG denied the presence of an infarction. In 18 cases with small Q III or Q aVF the VCG's were within normal limits. In two cases with normal Q III and Q aVF the VCG's did not detect the presence of an infarction in both cases.

The vectorcardiographic diagnosis of an inferior myocardial infarction was based on the superior orientation (at or above 360 degrees) of the 10, 20, 25 and 30-msec vectors in the frontal plane, superior displacement of the maximum QRS vector and clockwise rotation. In the left sagittal plane the 10, 20, 25 and 30-msec vectors were oriented at or above 180 degrees with the loop rotating counterclockwise.

The data presented suggest that vectorcardiography is a useful adjunct to electrocardiography in the diagnosis of an inferior myocardial infarction.

The Frank electrode system was employed, using the 5th intercostal space for placement of the precordial electrodes.^{2,5,6,11} The VCG's were recorded at or near the same time as the ECG's.

All patients had still loops recorded in the frontal, left sagittal and horizontal planes. In addition to the still loops, running loops at various speeds were recorded in order to provide a better analysis of the initial and terminal components of the QRS vector. The loops were interrupted every 2 milliseconds

(msec) and 1 millivolt standardization was recorded with each loop.

The amplitude and duration of the Q wave in Leads III and aVF of the ECG's were measured.

The following measurements were made in the frontal and left sagittal planes of the VCG's: Rotation of the QRS loop, presence or absence of "bites," and special attention was paid to the 10, 20, 25, 30 and 40-msec QRS vectors and the maximum deflection of the QRS vector. The magnitude in millivolt and duration in milliseconds in each of these vectors was recorded. Although the horizontal loops were reviewed, no measurements were obtained of the various vectors, since the abnormalities of an inferior myocardial infarction are not reflected in this plane. The Helm system was used to express the direction of the vectors.

Based solely on the analysis of the ECG's, the patients were divided into the following groups.

Group 1—A Q wave in Lead III and/or aVF which was equal or greater than 25 per cent of the amplitude of the R wave or equal or greater than 0.04 second in duration. The great majority of these cases also had Q waves in Lead II. Thirty-two patients satisfied these criteria, and the ECG's were considered in keeping with the diagnosis of inferior myocardial infarction.*

Group 2—A Q wave in Lead III and/or aVF equal to or greater than 0.04 second, but less than 25 per cent of the amplitude of the R wave or the reciprocal Q wave in Lead III and/or aVF with an amplitude equal to or greater than 25 per cent of the R wave, but less than 0.04 second duration. Twenty-one patients satisfied these criteria, and the ECG's were considered suggestive but not necessarily characteristic of an inferior myocardial infarction.

Group 3—A Q wave in Lead III and/or aVF, less than 0.04 second in duration and less than 25 per cent of the amplitude of the R wave. Twenty patients satisfied these criteria, and the ECG's were considered within normal limits. The Q waves in these leads were interpreted as not characteristic of an inferior myocardial infarction.

After the ECG's and VCG's had been analyzed, the hospital records were reviewed for the presence or absence of history of coronary disease. Only well documented cases were accepted.

RESULTS

Group 1—In this group, 16 of 32 patients had history of coronary heart disease manifested by a documented myocardial infarction in 13 and by angina pectoris in three. Seven of the above 13 with myocardial infarction also had angina pectoris.

*See References Nos. 1, 3, 4, 7, 9, 10, 13, 14, 16, 19, 20, 22.

Group 1A—There were 16 patients in this subgroup and none had a history of coronary disease. In only three cases was the frontal and sagittal plane VCG suggestive of an inferior myocardial infarction.

The range and average of the direction and magnitude of the 10, 20, 25, 30 and 40-msec vectors and of the maximum deflection vector in the frontal and sagittal planes are illustrated in Tables 1 and 2. Figure 1 illustrates the frequency of distribution of the 25 and 30-msec vectors in the frontal and sagittal planes.

Fourteen cases had clockwise and two had counterclockwise rotation in the frontal plane. The maximum deflection vector had an average direction of 18 degrees and was directed inferiorly in all but one case (Figure 2).

In the sagittal plane, counterclockwise rotation was found in 13 cases, clockwise in one case and figure-of-eight in two cases. The 10-msec vector was oriented superiorly in all cases. The maximum deflection vector had an average direction of 54 degrees.

Of the 32 patients in Group 1, 16 (Group 1A) had no history of coronary artery disease—represent 50 per cent electrocardiographic over-diagnosis of inferior myocardial infarction. The vectorcardiographic over-diagnosis of inferior myocardial infarction was 9.3 per cent—3 of 32 cases. (We are using over-diagnosis to indicate that there was no clue by history or previous electrocardiograms.)

Group 1B—There were 16 patients in this subgroup and all had a history of coronary heart disease. In two cases, the VCG did not confirm the presence of an inferior myocardial infarction (12.5 per cent).

In the frontal plane all patients with one exception (counterclockwise) had clockwise rotation. The 10-msec vector was oriented superiorly—that is, above the zero level—in all cases but one. The 30-msec vector was directed superiorly in 12 cases and the 40-msec vector was directed superiorly in four cases. The maximum deflection vector was directed inferiorly in 12 cases.

In the left sagittal plane, 13 patients had counterclockwise, two had clockwise and one had figure-of-eight rotation. The 10-msec vector was oriented superiorly in all cases. The 20-msec and 30-msec vectors were directed superiorly in 11 cases and 8 cases respectively. The maximum deflection vector was directed inferiorly in the majority of cases, the average direction being 86 degrees. This vector had an indeterminate direction in two cases (round loop).

The most consistent vectorcardiographic abnormality in this group with coronary disease was a superior orientation of the 10, 20, 25, and 30-msec vector above the zero degree in the frontal plane

TABLE 1.—Frontal plane: Range and averages of the direction and magnitude 10, 20, 25, 30 and 40-millisecond (msec) vectors and of the maximal deflection vector in the frontal plane

	10 msec-vector										20 msec						25 msec						30 msec						40 msec						Maximal Deflection Vector C	Rotation CC
	Direction Degree			Magnitude Millivolt			Direction Degree			Magnitude Millivolt			Direction Degree			Magnitude Millivolt			Direction Degree			Magnitude Millivolt			Direction Degree			Magnitude Millivolt								
	Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean							
Group I	A-16 Cases	208-360	295	0-0.5	0.23		30-360	331	0.2-2.1	0.66	360-30	349	320-45	9	0.1-2.8	1.01	222-130	38	0.2-2.3	0.82	240-120	50	14	2												
	B-16 Cases	225-347	227	0.1-0.4	0.24		20-355	309	0.2-0.8	0.54	270-358	322	35-355	351	0.4-1.2	0.85	362-70	23	0.2-2.2	0.8	310-180	10	15	1												
Group II	A-17 Cases	225-12	295	0.1-0.8	0.21		270-30	354	0.1-0.9	0.47	325-35	10	310-30	22	0.5-1.2	1.01	272-105	53	0.4-2.2	1.01	230-120	34	16	1												
	B-4 Cases	235-340	276	0.1-0.2	0.12		265-3	312	0.1-0.9	0.42	340-25	360	330-35	10	0.4-1.8	1.25	2-55	26	0.6-1.5	0.95	5-65	38	4	0												
Group III	A-18 Cases	215-12	288	0.1-0.5	0.19		250-64	6	0.1-1.2	0.56	5-70	25	360-45	31	0.2-2.4	1.23	20-130	58	0.8-1.9	1.11	10-100	38	18	0												
	B-2 Cases	335-325	330	0.2-0.1	0.15		11-15	13	0.7	0.7	14-22	18	19-38	28	1.3-1.5	1.4	15-55	35	0.7-1.5	1.1	30	30	2	0												

TABLE 2.—Sagittal plane: Range and averages of the direction and magnitude 10, 20, 25, 30 and 40-millisecond (msec) vectors and of the maximal deflection vector in the sagittal plane

	10 msec			20 msec			25 msec			30 msec			40 msec			Maximal Deflection Vector		Rotation C CC			
	Direction Degree	Magnitude Millivolt		Direction Degree	Magnitude Millivolt		Direction Degree	Magnitude Millivolt		Direction Degree	Magnitude Millivolt		Direction Degree	Magnitude Millivolt		Direction Degree	No. of Cases				
		Range	Mean		Range	Mean		Range	Mean		Range	Mean		Range	Mean				Range	Mean	Range
Group I 32 Cases	{ A-16 Cases B-16 Cases	270-26	200	0.1-0.4	0.26	325-14	178	0.2-1.2	0.48	220-10	125	0.3-2.6	0.76	4-360	115	0.2-2.3	0.82	5-240	54	1 +	13
		215-332	225	0.1-0.6	0.31	33-250	196	0.2-1.2	0.56	65-360	191	0.3-1.4	0.73	13-300	104	0.2-2.2	0.89	20-310	86	2 +	12
Group II 21 Cases	{ A-17 Cases B-4 Cases	170-285	230	0.1-0.4	0.19	10-325	171	0-0.9	0.42	25-240	158	0.3-1.5	0.67	2-347	50	0.4-2.2	1.01	10-350	62	3	13
		200-250	220	0.1-0.3	0.2	183-100	154	0.2-0.4	0.3	130-190	163	0.3-1.0	0.70	20-105	50	0.6-1.5	0.95	5-65	38	0	4
Group III 20 Cases	{ A-18 Cases B-2 Cases	90-230	200	0-0.4	0.20	95-225	157	0.2-0.9	0.39	85-190	130	0.2-2.4	0.73	12-120	55	0.4-1.9	1.11	10-86	43	1	17
		185-200	192	0.2-0.3	0.25	150-185	167	0.3-0.4	0.35	88-120	104	0.5-0.7	0.6	38-45	41	0.7-1.5	1.1	30	30	0	2

*Two, Figure 8.

†Figure 8.

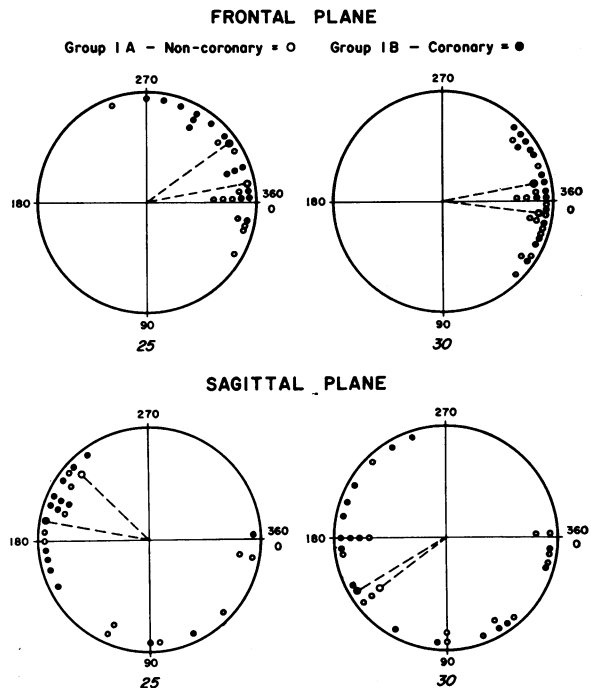


Figure 1.—Group 1.—Frequency distribution of the 25 and 30-msec vectors in the frontal and sagittal planes. The interrupted lines represent the average values. Compare with Figures 5 and 7.

with clockwise rotation. These findings were also associated with a superior displacement of the maximum deflection vector. In the sagittal plane, the most consistent findings for the diagnosis of an inferior myocardial infarction was the superior orientation of the 10, 20, 25, and 30-msec vectors above 180 degrees with counterclockwise rotation (Figures 3 and 4).

Group 2—There were 21 patients in this group.

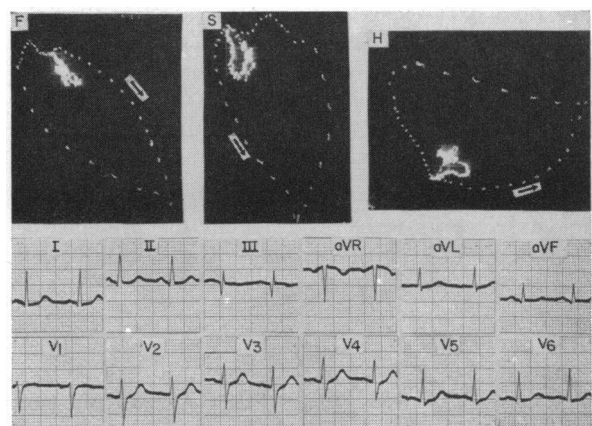


Figure 2.—Group 1A—Electrocardiogram and vectorcardiogram in a 49-year-old man without history of myocardial infarction. Note large Q waves in I, II, III, and aVR. The vectorcardiogram is within normal limits. The arrows in all illustrations indicate the direction of the loop. F=frontal plane; S=sagittal plane; H=horizontal plane.

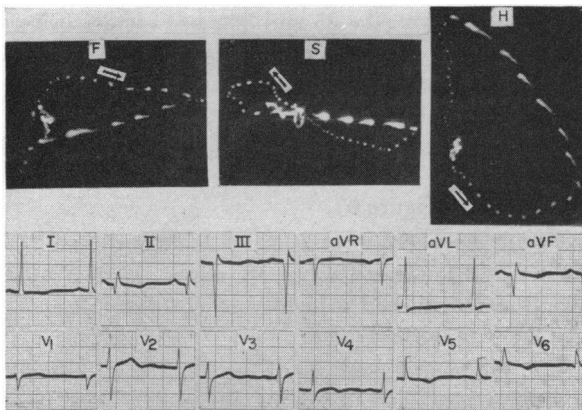


Figure 3.—Group 1B.—Electrocardiogram and vectorcardiogram in a 68-year-old man with history of myocardial infarction. Note the large Q waves in L II, L III and aVF. The vectorcardiogram is typical of an inferior myocardial infarction. The 10, 20, 25 and 30-msec vectors in the frontal plane are oriented superiorly. Note figure-of-eight rotation in the sagittal plane with the initial portion of the loop rotating counterclockwise.

Group 2A—There were 17 patients in this subgroup and none had history of coronary disease. In no case was the VCG indicative of an inferior myocardial infarction. In two cases the frontal plane loop was suggestive; however, the sagittal plane 30-msec vector in both was directed below 180 degrees. Neither case was thus considered characteristic of inferior myocardial infarction.

The range and average of the direction and magnitude of the 10, 20, 25, 30 and 40-msec vectors and of the maximum deflection vector in the frontal and sagittal planes are illustrated in Tables 1 and 2. Figure 5 illustrates the frequency distribution of the

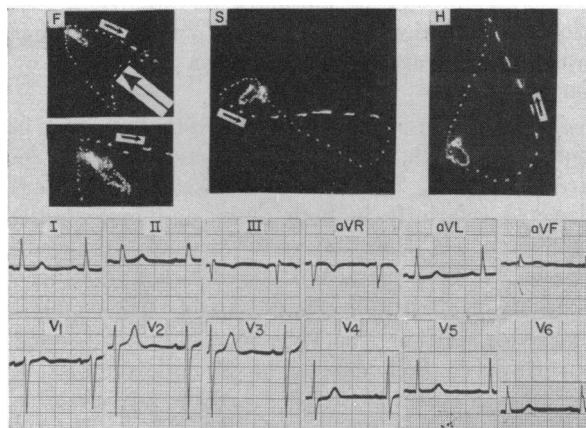


Figure 4.—Group 1B.—Electrocardiogram and vectorcardiogram in a 77-year-old woman with history of myocardial infarction. Note large Q waves in L III and compare with Figure 2. There is no Q wave in aVF. The frontal loop shows normal orientation of the 10, 20, 25 and 30-msec vectors. Note a large bite in the mid-portion of the QRS loop (arrow). Observe the rotation of the sagittal loop and compare with Figure 3. This vectorcardiogram is compatible with the diagnosis of an inferior myocardial infarction.

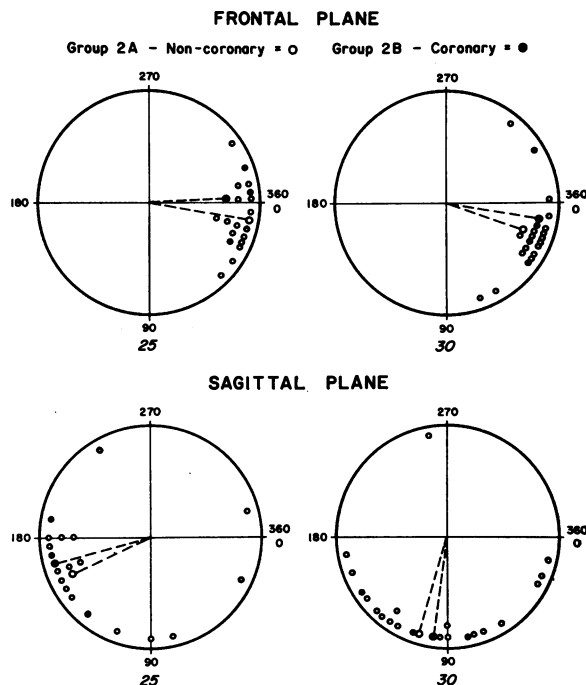


Figure 5.—Group 2—Frequency distribution of the 25 and 30-msec vectors in the frontal and sagittal planes. The interrupted lines represent the average values. Compare with Figures 1 and 7.

(Figure 6 follows on Page 172)

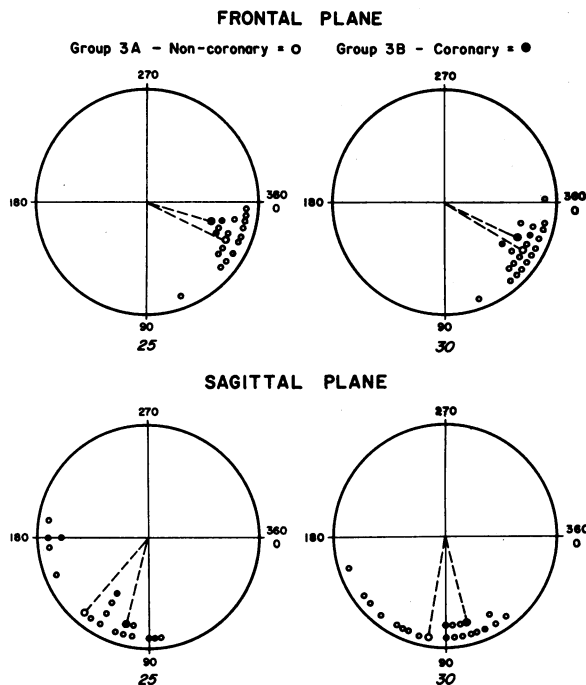


Figure 7.—Group 3—Frequency distribution of the 25 and 30-msec vectors in the frontal and sagittal planes. The interrupted lines represent the average values. Compare with Figures 1 and 5.

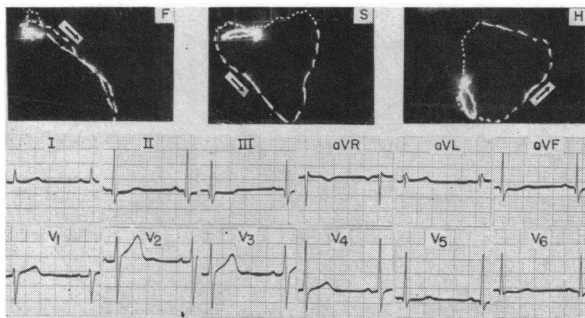


Figure 6.—Group 2B—Electrocardiogram and vectorcardiogram in a 63-year-old man with history of myocardial infarction. Note the small Q waves in I, III and aVF. The vectorcardiogram is not suggestive of an inferior myocardial infarction.

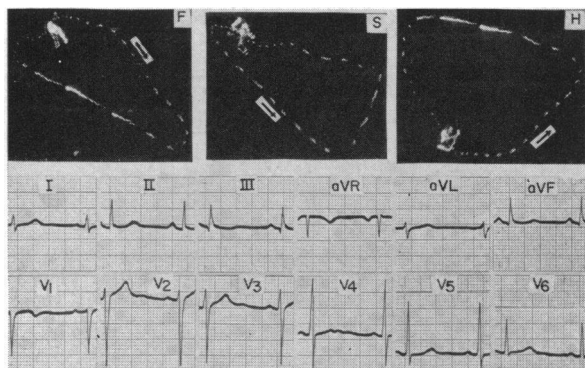


Figure 8.—Group 3B—Electrocardiogram and vectorcardiogram in a 51-year-old man with history of myocardial infarction. Note the small Q waves in I, III, and aVF. The vectorcardiogram does not suggest the diagnosis of an inferior myocardial infarction.

direction of the 25 and 30-msec vectors in the frontal and sagittal planes.

In the frontal plane 16 patients had clockwise and one case counterclockwise rotation. The 20 and 30-msec vectors were oriented superiorly in eight and three cases respectively. The maximum deflection vector had an average direction of 67 degrees and in only two cases was it directed superiorly.

In the sagittal plane, the rotation was counterclockwise in all but one case.

The 20 and 30-msec vectors were oriented superiorly in six and three cases respectively. The maximum deflection vector had an average of 93 degrees with superior direction in only two cases.

Group 2B—The four patients in this subgroup all had history of coronary disease. In no case was the VCG considered diagnostic of an inferior myocardial infarction.

The VCG in the frontal plane was suggestive (but not diagnostic) of an inferior infarct in only one case in which the 10, 20, 25, and 30-msec vectors were directed above 360 degrees with clockwise rotation and a superior displacement of the QRS vector. In this case, the maximum QRS vector was 14

degrees. However, the 25 and 30-msec vectors in the sagittal plane were at 170 degrees and 147 degrees respectively and, therefore, did not substantiate the frontal plane findings.

The remaining three cases showed a 30-msec vector below zero degree with clockwise rotation of the frontal loop (Figure 6).

Group 3—There were 20 cases in this group.

Group 3A—There were 18 cases in this subgroup and none had a history of coronary disease. The VCG was normal in all.

The range and averages of the 10, 20, 25, 30 and 40-msec vectors and of the maximum deflection vector in the frontal and sagittal planes are illustrated in Tables 1 and 2. Figure 7 illustrates the frequency distribution of the 25 and 30-msec vectors in the frontal and sagittal planes.

The frontal loop had clockwise rotation in all cases. Superior orientation of the 10 and 20-msec vectors was found in three and six cases respectively. The 25, 30 and 40-msec vectors were inferiorly oriented in all cases. The maximum QRS deflection vector had an average direction of 38 degrees.

In the sagittal plane the rotation was counterclockwise in 17 cases and a figure-of-eight in one case.

The 25-msec vector was directed superiorly in three cases. The 30 and 40-msec vectors were directed inferiorly in all cases. The maximum deflection vector had an average direction of 43 degrees and in two cases the maximum deflection vector was undetermined.

Group 3B—In the two cases in this subgroup there was history of coronary disease. Both had clockwise rotation in the frontal plane. In neither was the VCG suggestive of inferior myocardial infarction.

The 10-msec vector was superiorly oriented in both cases with an average direction of 330 degrees. The 20, 25, 30 and 40-msec vectors were directed inferiorly in both cases, and in both the maximum QRS deflection vector had an average direction of 29 degrees and was directed inferiorly.

In the sagittal plane, both patients had counterclockwise rotation. The 10-msec vector was directed superiorly in both cases. The 20-msec vector had an average direction of 167 degrees and in one case it was directed at 185 degrees. The 25, 30 and 40-msec vectors were directed inferiorly in both cases. The maximum deflection vector was at 30 degrees in one case and in the other case it was undetermined.

In the two patients with history of coronary disease and with normal ECG's, the VCG's did not detect the presence of an infarct (Figure 8).

The magnitude of the 10, 20, 25, 30 and 40-msec vectors were not significantly different in the three groups studied.

DISCUSSION

Despite the fact that there are sound practical reasons for distinguishing between electrocardiography and vectorcardiography, it is important to recognize that both methods record potential variations of cardiac electrical activity and that they represent only different views of this same activity. However, it is equally important to appreciate that the high resolution of the vectorcardiographic units, the accessibility of information and the distribution of electrodes in the body surface having different electrical resistances, appears to make vectorcardiography a useful additional adjunct to electrocardiography. In some circumstances, it provides information which may not be present in electrocardiograms. The inertia of the direct writer recorder and blurring of the baseline make for another reason that electrical information may be lost with routine electrocardiography.

The observations reported here, like those of other investigators^{1,7,10,14} show that it is impossible to separate completely, by the ECG, cases with inferior myocardial infarction from those without infarction in which Q waves are present in L III and aVF. Although there was some overlapping in the measurements made in the VCG's (Figures 1, 5 and 7), the findings suggest that vectorcardiography appears to be a useful tool in making this differentiation in the majority of cases. The VCG's are most useful in cases in which a Q wave of a significant magnitude is recorded in L III and/or aVF of the ECG. In these circumstances the VCG's appear to separate the infarction cases from the non-infarction cases better than the ECG. This is documented by the fact that in Group 1B, all 16 cases with history of coronary disease had the electrocardiographic diagnosis confirmed by the VCG. On the other hand, in 13 of the 16 cases of Group 1A with prominent Q III or aVF, and with absence of history of coronary disease, diagnosis of an inferior myocardial infarction was not substantiated by the VCG.

In addition, the diagnosis of an inferior myocardial infarction was questionably present in the ECG of 21 cases in Group 1. In all of the 17 cases (Group 2A) without history of coronary disease, the VCG excluded the diagnosis of an inferior myocardial infarction. In the remaining four cases with coronary disease and with questionable electrocardiographic findings (Group 2B) the VCG did not support the diagnosis of an infarction. Furthermore, in all of the 18 cases in Group 3A with no history of myocardial infarction (small Q waves in L III and aVF), the VCG's substantiated the electrocardio-

graphic diagnosis. In the remaining two cases of this group, in which there was no history of coronary disease, both the ECG and VCG were within normal limits.

It is thus evident that the VCG's are most helpful in the presence of a Q wave in L III and aVF of the ECG, and least useful when no Q wave or when a small Q wave is present in the ECG.

The most useful criterion, and the one which provided the most reliable vectorcardiographic diagnosis for an inferior myocardial infarction was the superior orientation above the zero degree of 10, 20, 25 and 30-msec vectors in the frontal plane with the superior displacement of the maximum QRS vector, as has been suggested by other investigators.^{8,12,18,21} The clockwise rotation of the frontal loop was also of importance since it helped to differentiate an inferior myocardial infarction from the superiorly oriented vectors of left ventricular hypertrophy. In the presence of left ventricular hypertrophy, although these vectors may be oriented superiorly, the frontal loop almost invariably rotates counterclockwise.

The presence of "bites" or notches alone was not in itself diagnostic of an infarction. However, in cases with the 10, 20, 25 and 30-msec vectors oriented superiorly, the "bites" or notches helped to substantiate the presence of an infarction. (Figure 4.)

In addition to the abnormalities in the frontal plane, the sagittal plane was of significance in the diagnosis of an inferior infarction.¹⁷ For this diagnosis to be made with confidence, the 10, 20, 25 and 30-msec vectors should be oriented superiorly above 180 degrees and with counterclockwise rotation of the QRS loop. If the loop rotates in a figure-of-eight, the initial component should rotate counterclockwise. If these criteria are satisfied, the possibility of over-diagnosis of inferior myocardial infarction is greatly reduced.

In conclusion, vectorcardiography appears to be a useful technique in the diagnosis of an inferior myocardial infarction. It is most helpful when a Q wave is present in L III and/or aVF of the ECG.

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